

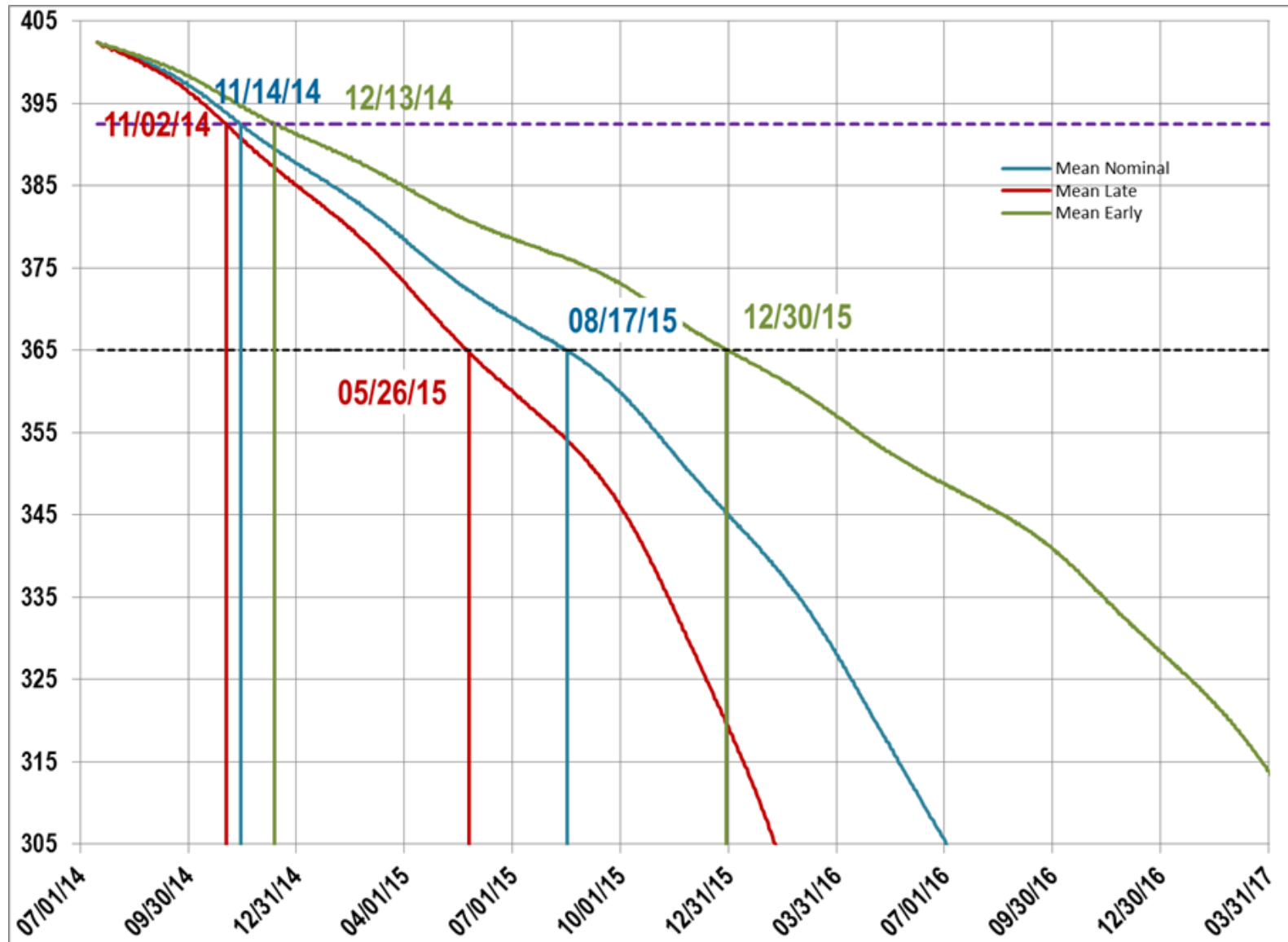
# JAXA TRMM Science status

## End-of-Mission Experiment Plan for TRMM/PR

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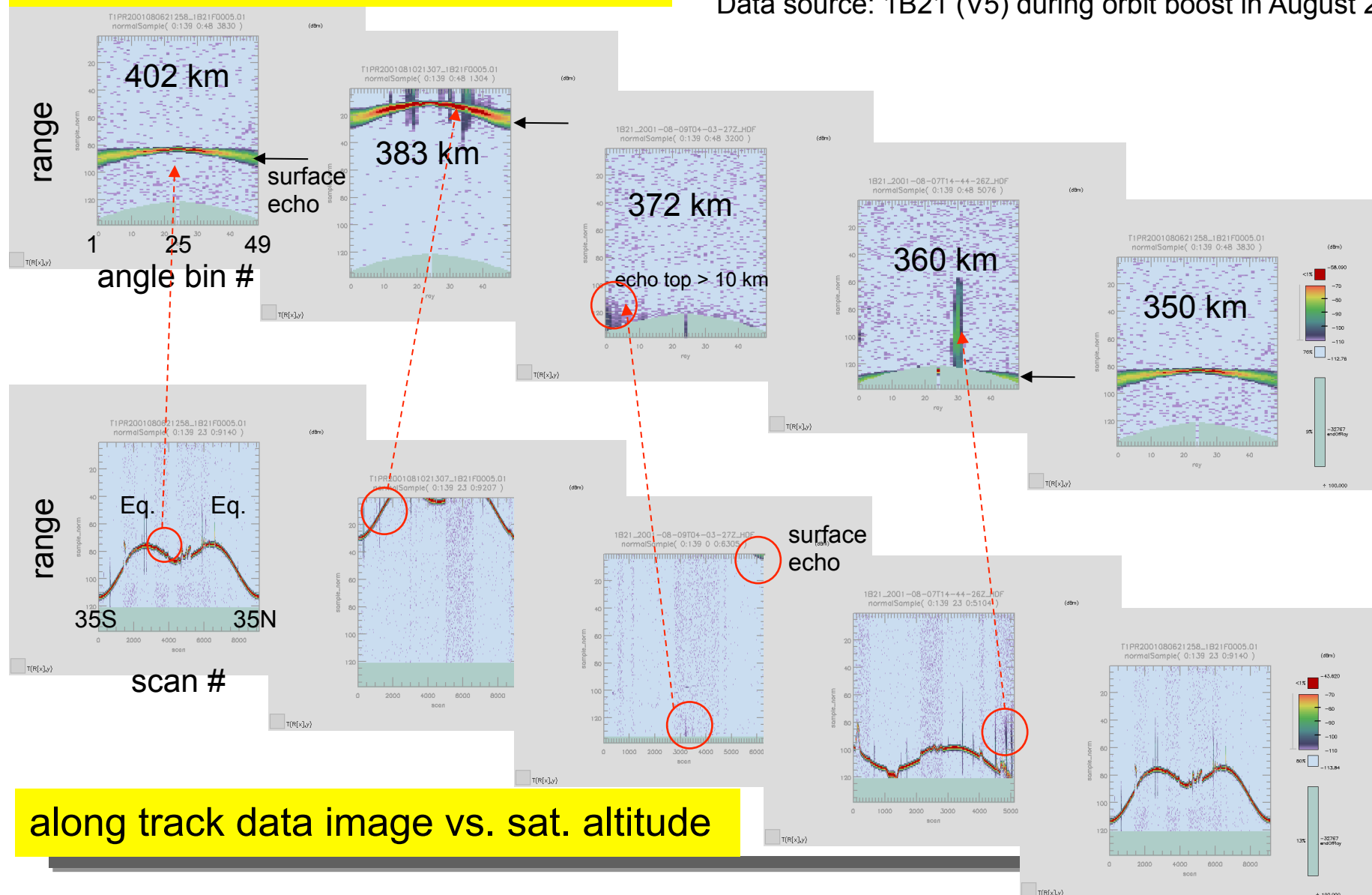
Nobuhiro Takahashi (NICT)  
2014.08.05

- PR observation during the descent
- Proposed experiments and schedule
- Overview of each experiment
- Summary and discussion items



## scan data image vs. sat. altitude

Data source: 1B21 (V5) during orbit boost in August 2001.



## along track data image vs. sat. altitude

# Proposed experiments (as Dec. 2012)

|  |   | purpose                   | operation  | risks   | note  |  |
|--|---|---------------------------|--|---|---|--|
| Normal observation                                       | 1 | Nominal observation       | 1.Comparison with GPM/ DPR. 2. Increase the rain record by radar. 3. Testing GSMP. | Nominal observation                                     | No risk.  | Retrieved data may be valid until the radar observed up to 5 km in height. |
|  | 2 | Radiometer a mode         | Use the PR as radiometer   | Nominal obs. and RF off.                                | Medium risk on the RF on/off.                         | During obs. window is out of the rain layer.                               |
|  | 2 | Dense b sampling          | Increase the data on the non uniform beam filling effect.                          | External cal. mode                                      | No risk. This mode is part of nominal obs. chain.     | Need to have certain depth of rain layer.                                  |
|  | 2 | KaPR scan c simulation    | To obtain the reference data of KaPR scanning with Ku-band radar.                  | Nominal obs. Mode with modified phase code              | Minor risk. Need to upload the phase data.*           | Need to have certain depth of rain layer.                                  |
|  | 2 | Wider d swath experiment  | To check the possibility to enlarger the swath                                     | External cal. mode or Nominal obs. Mode                 | Minor risk. Need to upload the phase data.            | This mode is available when the obs. Window covers only near surface.      |
| Experimental observation w/ modified satellite operation | 3 | 90 deg. yaw a observation | To obtain the detailed rain structure and sigma zero                               | Nominal obs. mode with satellite yaw angle of 90 deg.   | Unknown risks for 90 deg. yaw operation.              | Unknown impacts to other instruments (TMI, VIRS, LIS)                      |
|  | 3 | Pitch b maneuver          | To obtain the clutter data against pitch angle.                                    | Nominal obs. mode with pitch angle of 0.5 to 4 degrees. | Less risk to S/C. Negligible impact to TMI algorithm. | Useful for the antenna design of spaceborne radar                          |
| Engineering experiment                                   | 4 | checkout                  | To obtain the engineering information of PR  | Various modes   | Unknown risk.   | Need to limit the checkout items to avoid risks.                           |

\*: This mode was tried and succeeded in the previous experiment.

# Risk assessment (as Dec. 2012)

|        |                         | <b>purpose<br/>(scientific significance)</b>  | <b>operation<br/>(duration)</b>  | <b>impact to S/C and<br/>instruments (risks)</b>                         | <b>note</b>  | <b>Priority</b> |
|--------|-------------------------|---|--|--|--|-----------------|
| 1      | Nominal observation     | 1.Comparison with GPM/DPR.<br>2. Increase the rain record by radar.<br>3. Testing GSMaP.<br><b>(High)</b> | Nominal observation<br>(As long as the obs.<br>window covers surface<br>to 5km)                            | No risk.<br><b>(Low)</b>   | Retrieved data may be<br>valid until the radar<br>observed up to 5 km in<br>height.                    | <b>1</b>        |
| 2<br>a | Radiometer mode         | Use the PR as high resolution<br>radiometer to compare with<br>TMI. <b>(Medium)</b>                       | Nominal observation<br>and RF off.<br>(see note)   | Medium risk on the RF<br>on/off. <b>(Medium)</b>                         | During obs. window is out<br>of the rain layer.  | <b>3</b>        |
| 2<br>b | Dense sampling          | Increase the data on the non<br>uniform beam filling effect for<br>DPR L2. <b>(High)</b>                  | External cal. mode<br>(10 days)  | No risk. This mode is part<br>of nominal obs. chain.<br><b>(Low)</b>     | Need to have certain depth<br>of rain layer.   | <b>1</b>        |
| 2<br>c | KaPR scan simulation    | To obtain the reference data of<br>KaPR scanning with Ku-band<br>radar. <b>(Medium)</b>                   | Nominal obs. Mode<br>with modified phase<br>code. (10 days)  | Minor risk.<br>Need to upload the phase<br>data.* <b>(Low)</b>           | Need to have certain<br>depth of rain layer.   | <b>2</b>        |
| 2<br>d | Wider swath experiment  | To check the possibility to<br>enlarger the swath for future<br>radar design. <b>(High)</b>               | External cal. mode or<br>Nominal obs. Mode<br>(10 days)  | Medium risk.<br>Need to upload the phase<br>data. <b>(Medium)</b>        | This mode is available<br>when the window is out of<br>the rain layer.                                 | <b>2</b>        |
| 3<br>a | 90 deg. yaw observation | To obtain the detailed rain<br>structure and sigma zero<br><b>(High)</b>                                  | Nominal obs. mode<br>with satellite yaw angle<br>of 90 deg.<br>(total 10 days)                             | Unknown risks for 90 deg.<br>yaw operation for S/C.<br><b>(High)</b>     | Unknown impacts to other<br>instruments (TMI, VIRS,<br>LIS)  | <b>3</b>        |
| 3<br>b | Pitch maneuver          | To obtain the clutter data<br>against pitch angle.<br><b>(Medium)</b>                                     | Nominal obs. mode<br>with pitch angle of 0.5<br>to 4 degrees w/ 0.5<br>deg. intervals.<br>(minimum 2 days) | Less risk to S/C.<br>Negligible impact to TMI<br>algorithm. <b>(Low)</b> | Useful for the antenna<br>design of spaceborne<br>radar  | <b>2</b>        |
| 4      | checkout                | To obtain the engineering<br>information of PR.<br><b>(Low)</b>   | Various modes<br>(1 -2 weeks)  | Unknown risk.<br><b>(Medium to High)</b>                                 | Need to limit the checkout<br>items to avoid risks.<br>(implement at the end of<br>the PR experiments) | <b>4</b>        |

\*: these modes were tried and succeeded in the previous experiment.

# Proposed experiments (as Jul. 2014)

|  |   | purpose                 | operation   | risks   | note  |  |
|--|---|-------------------------|---|---|---|--|
| Normal observation                                       | 1   | Nominal observation     | 1.Comparison with GPM/ DPR. 2. Increase the rain record by radar. 3. Testing GSMaP. | Nominal observation                                   | No risk.  | Retrieved data may be valid until the radar observed up to 5 km in height. |
|  | (Enough data can be obtained without RF off during descending ) |                         |   |   |   |  |
| Experimental observation                                 | 2 b   | Dense sampling          | Increase the data on the non uniform beam filling effect.                           | External cal. mode                                    | No risk. This mode is part of nominal obs. chain. | Need to have certain depth of rain layer.                                  |
|  | ( 2b can cover this experiment )                                |                         |   |   |   |  |
| Experimental observation w/ modified satellite operation | 2 d   | Wider swath experiment  | To check the possibility to enlarger the swath                                      | External cal. mode or Nominal obs. Mode               | Minor risk. Need to upload the phase data.        | This mode is available when the obs. Window covers only near surface.      |
|  | 3 a   | 90 deg. yaw observation | To obtain the detailed rain structure and sigma zero                                | Nominal obs. mode with satellite yaw angle of 90 deg. | Unknown risks for 90 deg. yaw operation.          | Unknown impacts to other instruments (TMI, VIRS, LIS)                      |
| Engineering experiment                                   | ( DPR has already done this experiment )                        |                         |   |   |   |  |
|  | 4   | checkout                | To obtain the engineering information of PR   | Various modes   | Unknown risk.                                     | Need to limit the checkout items to avoid risks.                           |

\*: This mode was tried and succeeded in the previous experiment.

# Detailed experiment schedule (as Jul. 2014)

Experimental observation

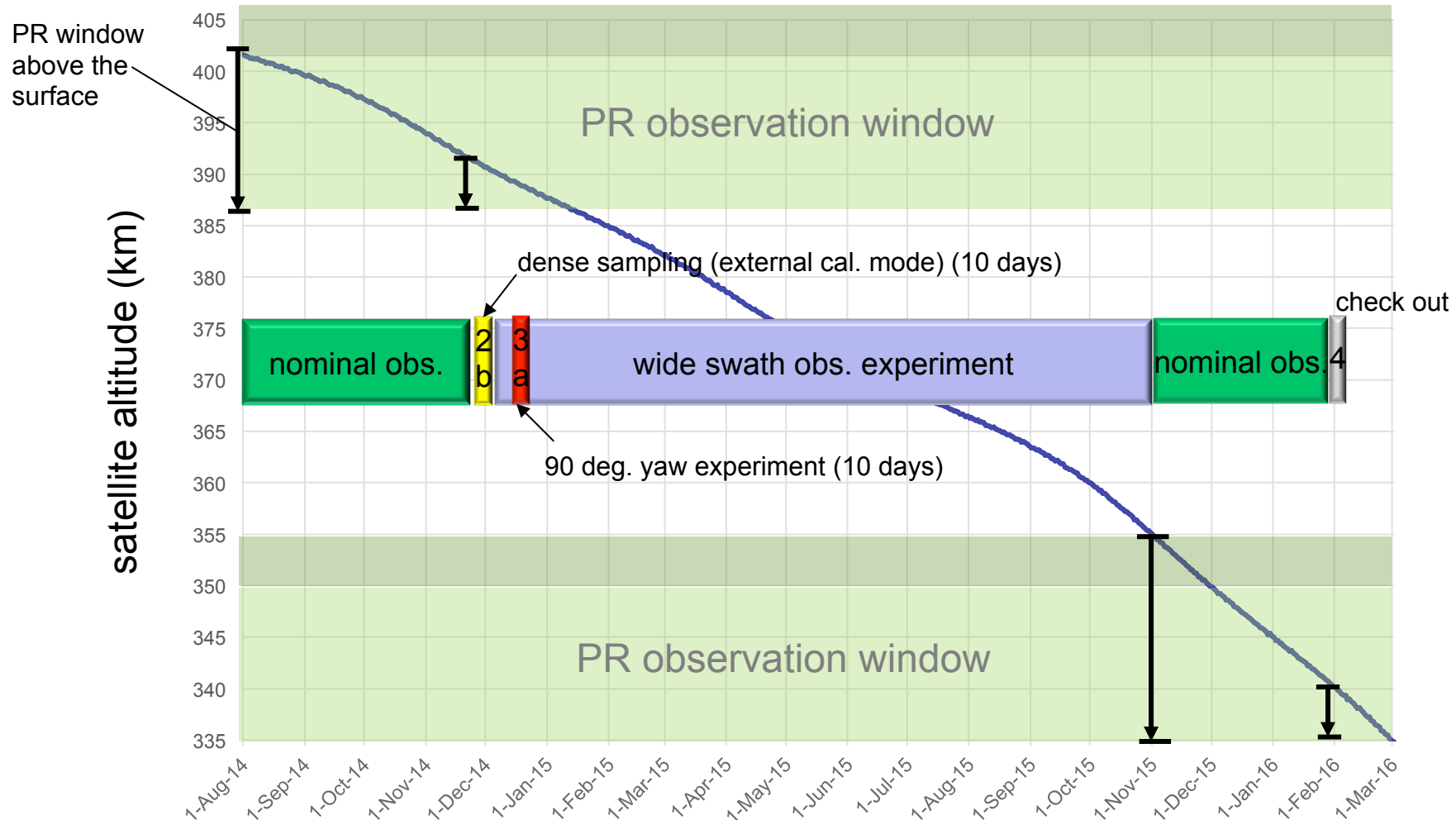
|                              | purpose  | operation   | altitude window(s) or duration            | note  |
|------------------------------|--|---|---|---|
| 1 Nominal observation        | 1.Comparison with GPM/DPR. 2. Increase the rain record by radar. 3. Testing GSMap. | Nominal observation                                   | 402.5 to 392.5 km<br>And<br>355 to 340 km | Retrieved data may be valid until the radar observed up to 5 km in height.  |
| 2 Dense b sampling           | Increase the data on the non uniform beam filling effect.                          | External cal. mode                                    | 392.5 to 390 km<br>(10 days)              |   |
| 2 Wider swath d experiment   | To check the possibility to enlarge the swath                                      | External cal. mode or Nominal obs. Mode               | 390 to 355 km<br>(11 month)               | Need to upload of the phase code for three times according to the satellite altitude.                                   |
| 3 90 deg. yaw a observation* | To obtain the detailed rain structure and sigma zero from various incident angle.  | Nominal obs. mode with satellite yaw angle of 90 deg. | 390 to 355 km<br>(total 10 days)          | 4 yaw maneuvers per day and each time about 22 min. observation.<br>Combining with wider scan experiment is preferable. |
| 4 checkout                   | To obtain the engineering information of PR  | Various modes   | Below 340 km                              | Implementation has not been decided.  |

Note: Altitude and duration of each experimental observation may change due to the satellite operation (e.g. 180 deg. Yaw turn) and the satellite condition.

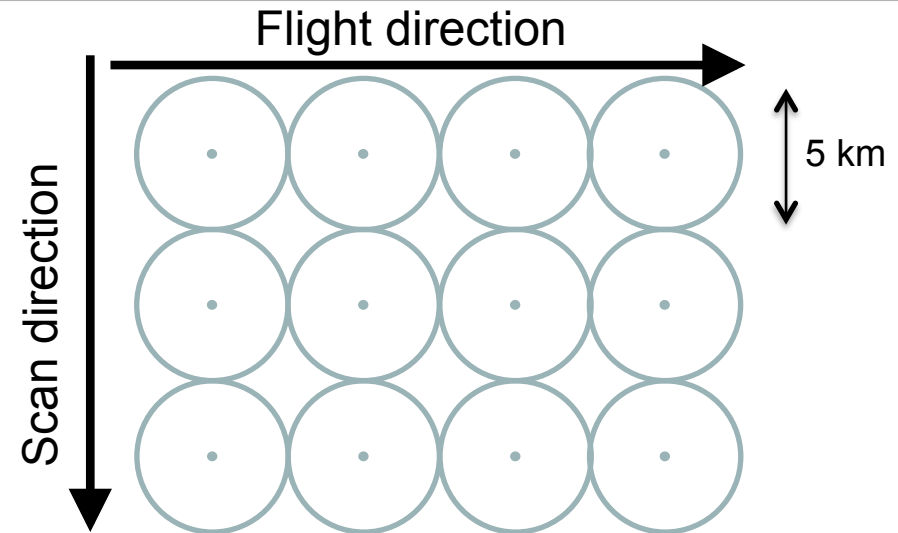
\*: see NASA's slides for GISM on 5 June 2014.



- nominal altitude prediction case



### Nominal observation

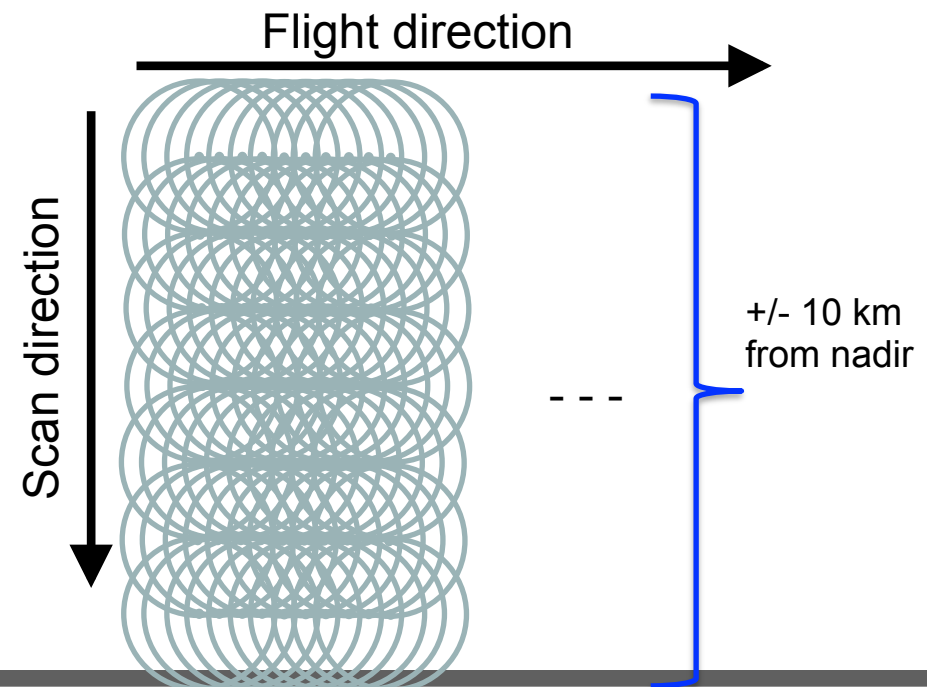


### Dense observation (external cal. mode)

2 times dense for scan direction  
7 times dense for flight direction

Need to do:

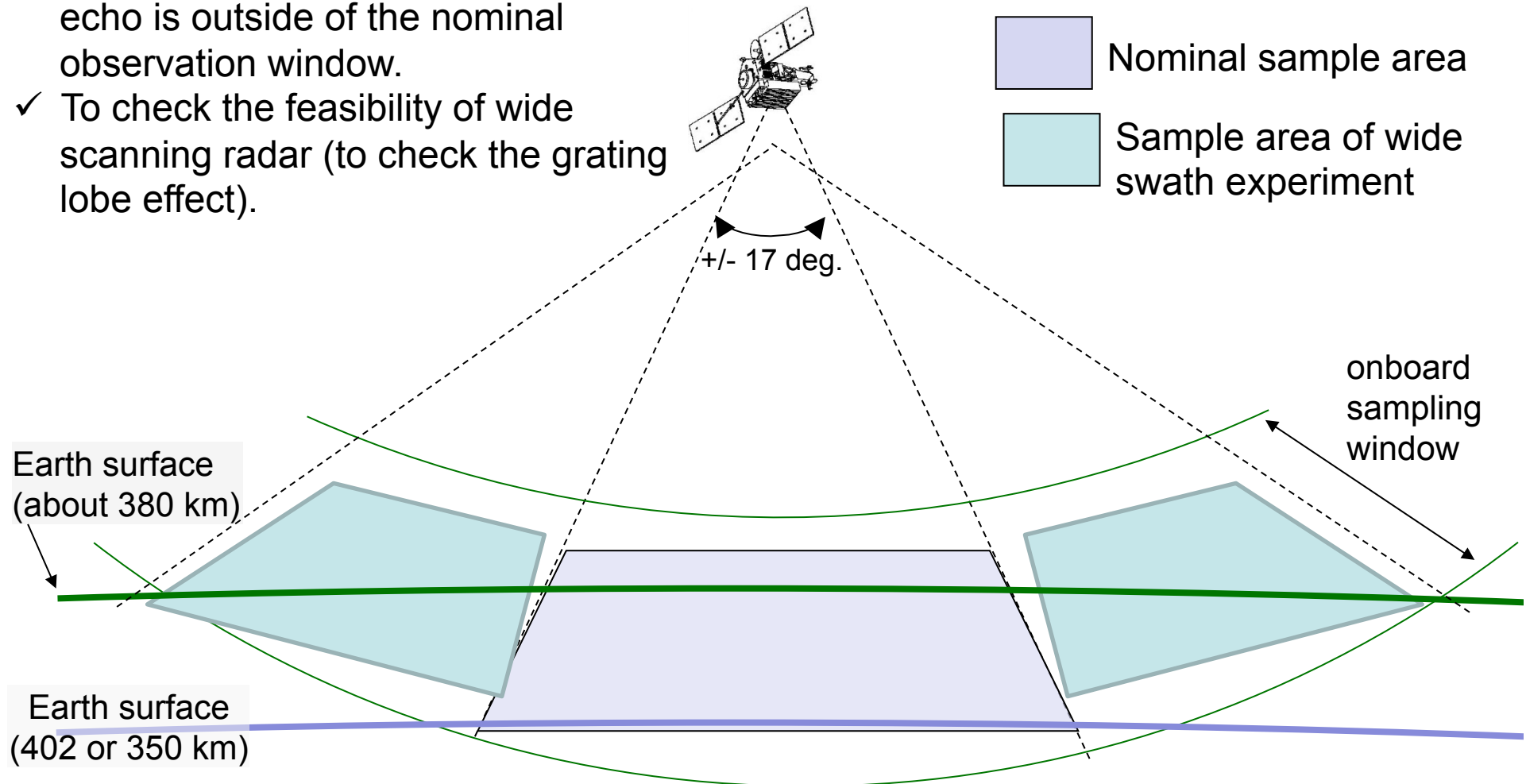
- ❑ Development of L1B21 interface.

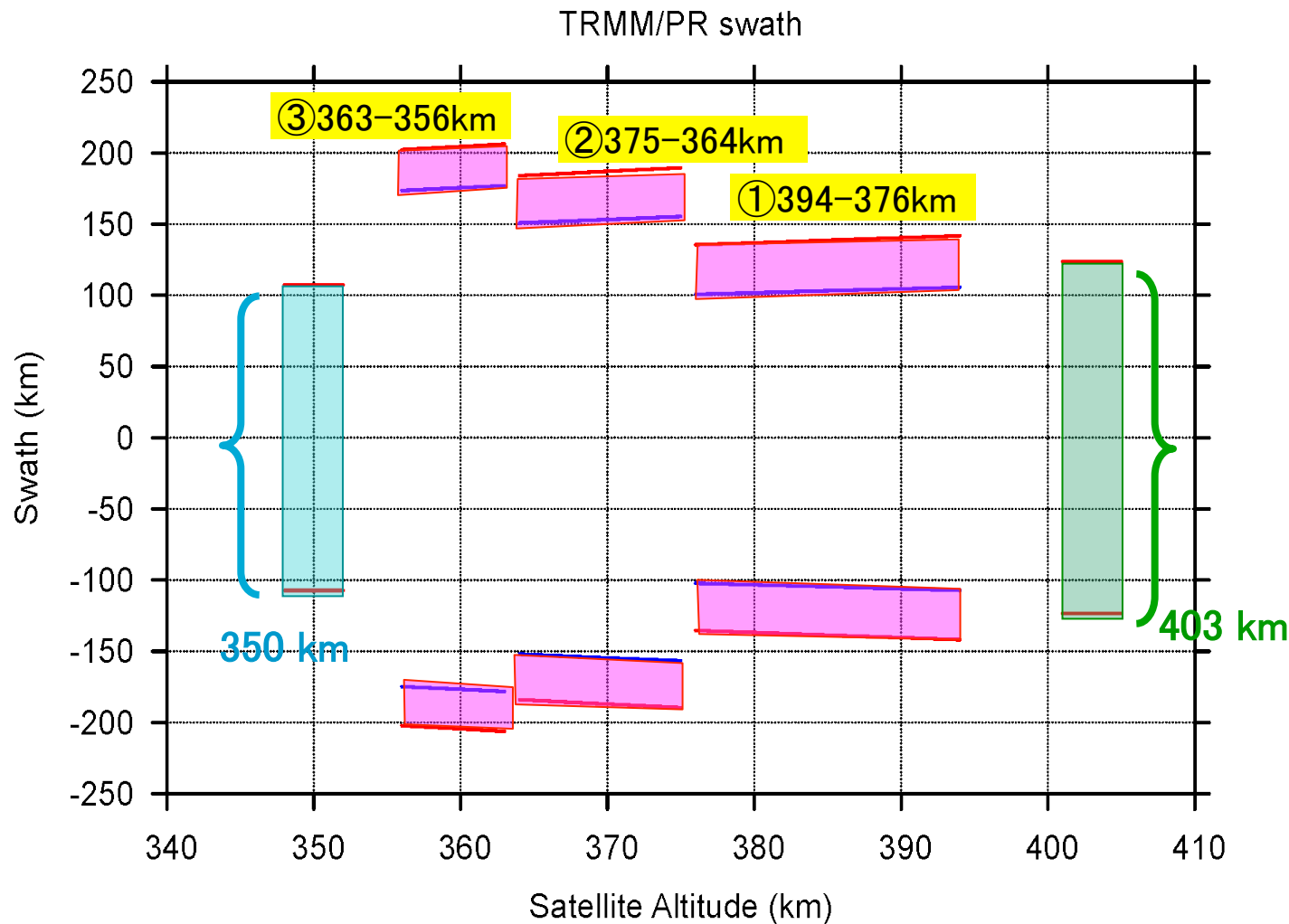


# 2d Wide swath experiment

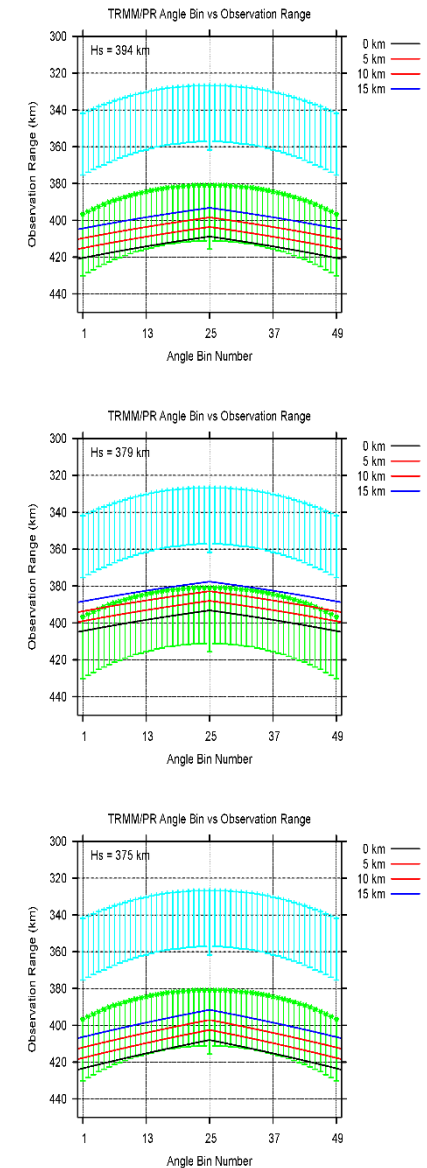
Implemented when the satellite altitude is between 390 and 355 km

- ✓ To observed rain echo where rain echo is outside of the nominal observation window.
- ✓ To check the feasibility of wide scanning radar (to check the grating lobe effect).

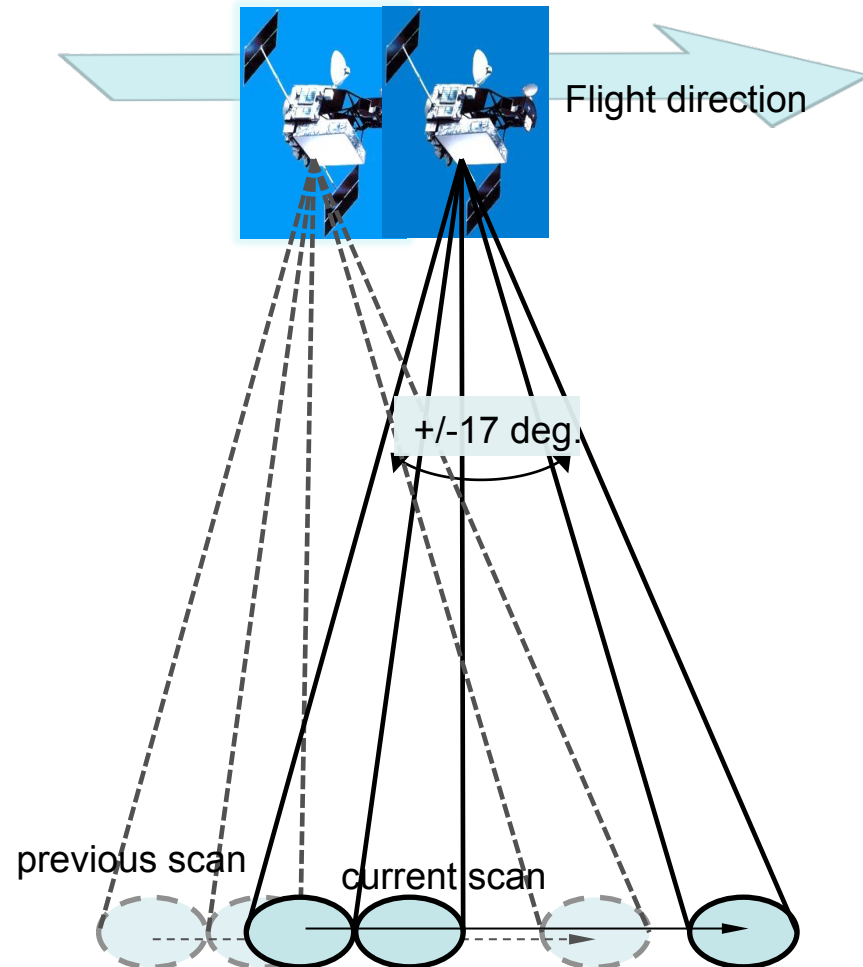
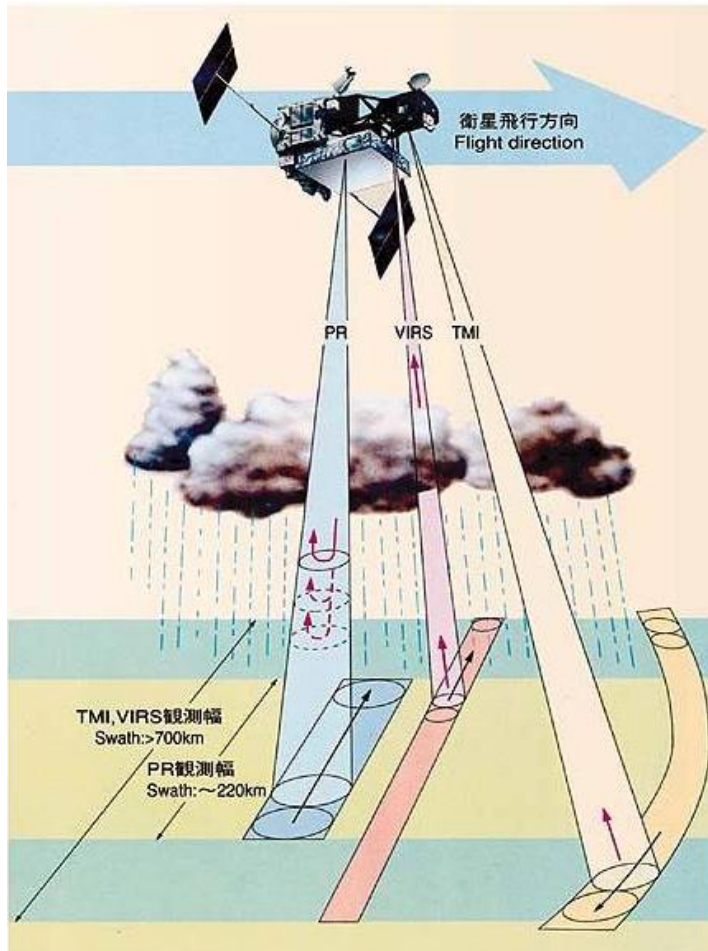




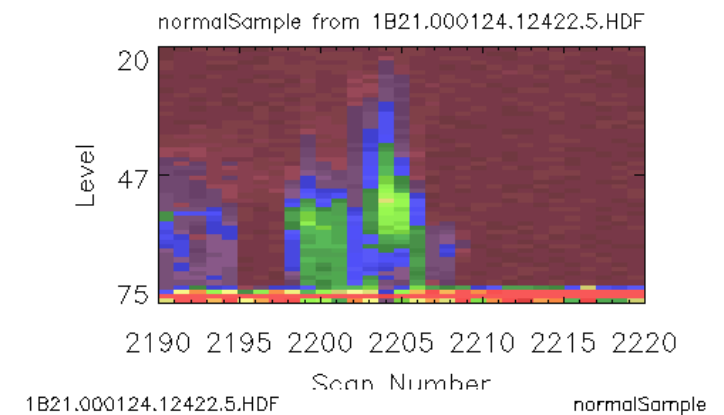
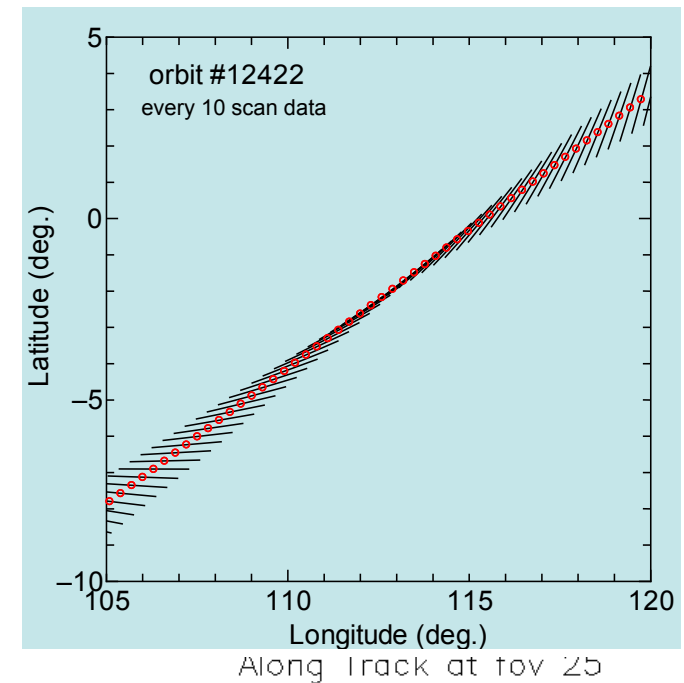
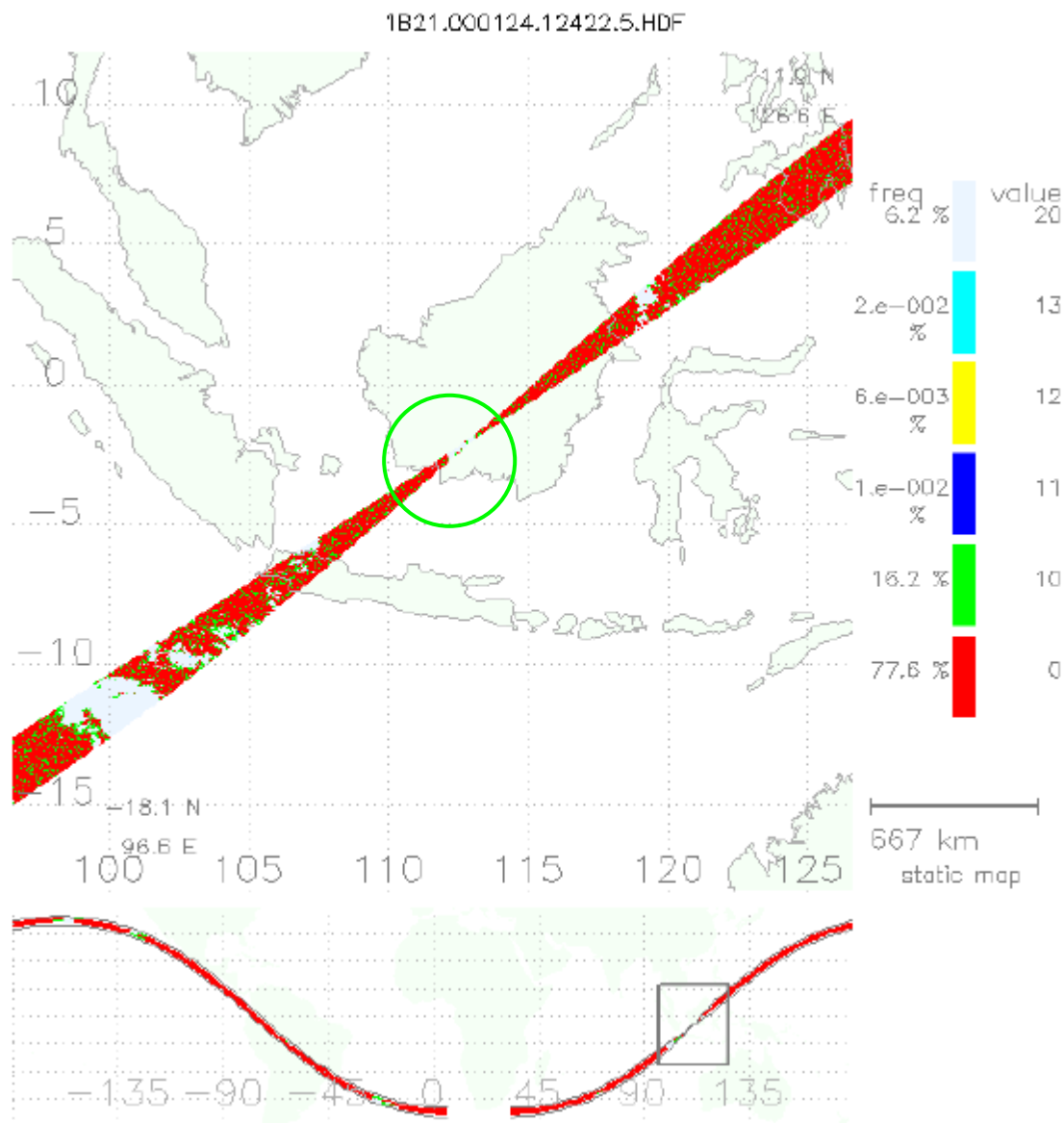
- Issues:
  - Higher main lobe clutter
  - Grating lobe effect



Nominal observation → 90 deg. yaw



This mode can obtain the rain structure with various incident angles.  
TMI will also observe similar data.

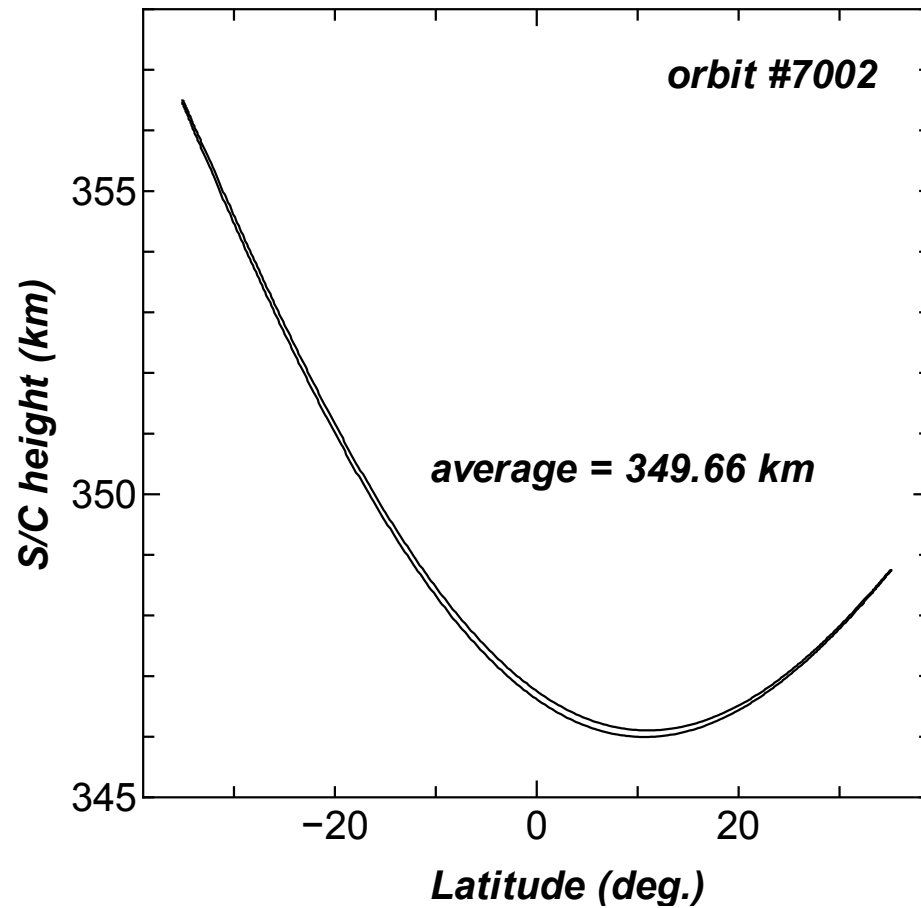


# Summary and discussion items

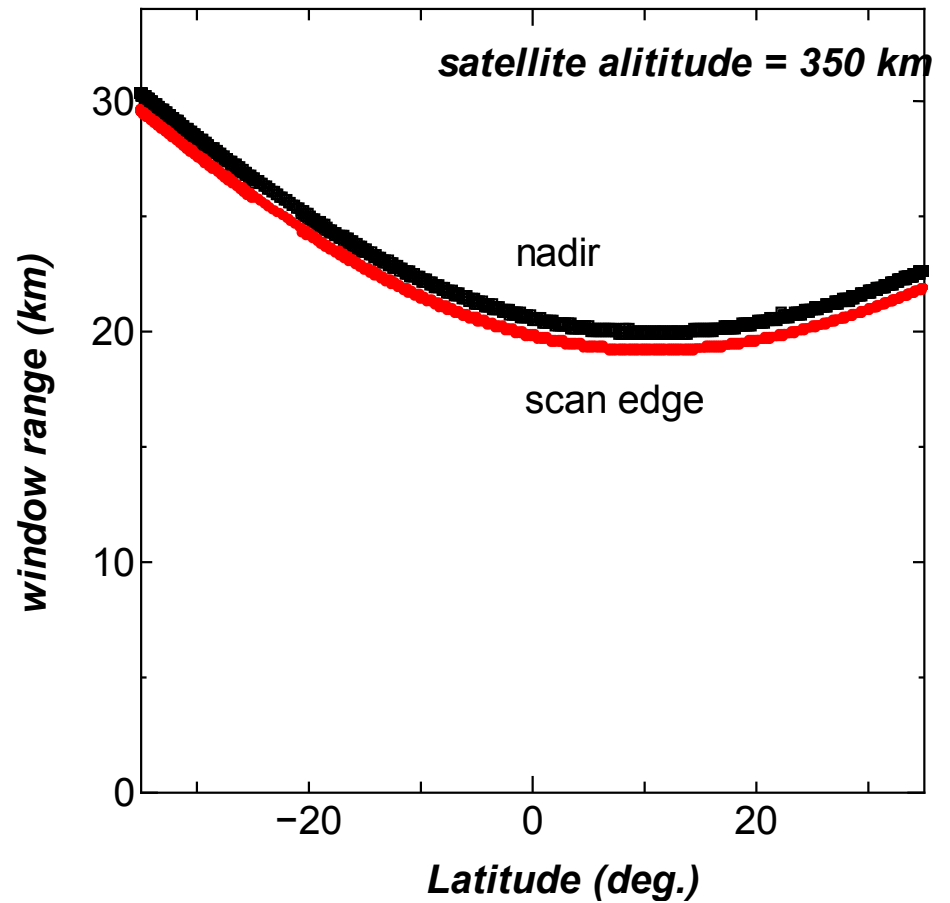
- Summary: proposed experiments:
  - Dense data sampling with external calibration mode (10 days in 392-390 km)
  - Wider swath experiment (390-355 km)
  - 90 deg. yaw maneuver experiment (10 days in 390-355 km). Combination of wider swath experiment is preferable.
- Impact to the other sensors and satellite bus
  - Need a special operation during the 90 deg. yaw maneuver. TMI's scan direction will be also fore- and aft-looking observation. Note that NASA ESMO team has checked the feasibility of the experiment.
  - Feedback from TMI team: it is required to avoid this experiment when the satellite altitude approaches to near 350 km.
- Discussion items:
  - timing of 90 deg. yaw experiment (current proposal is when the both the nadir and the wider scan observation is available. e.g. between 390 and 380 km.
  - Need to determine the priority of the sensor in case the battery 2 is degraded more.



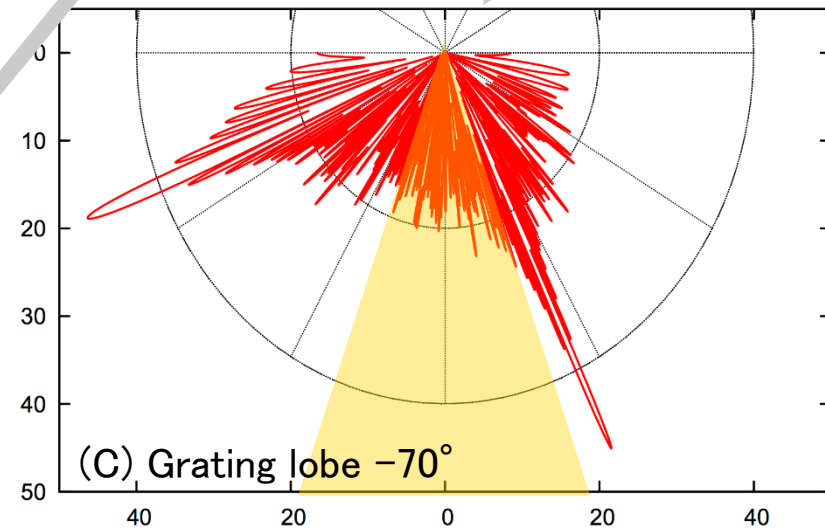
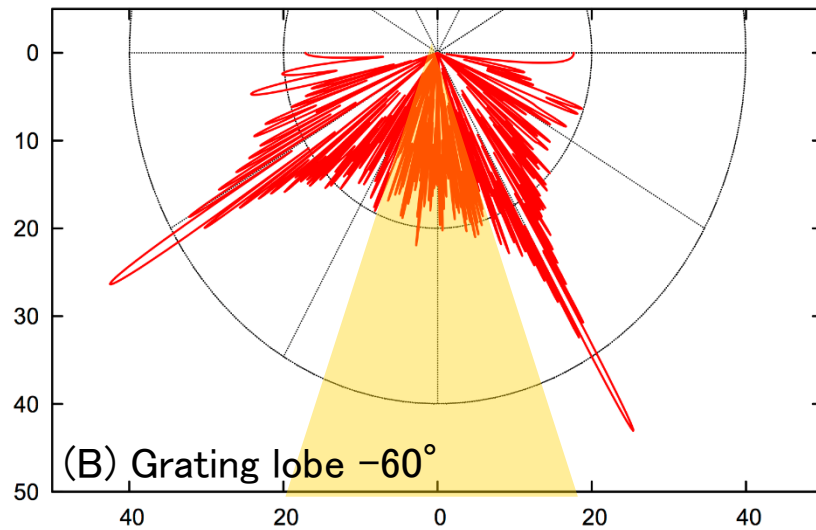
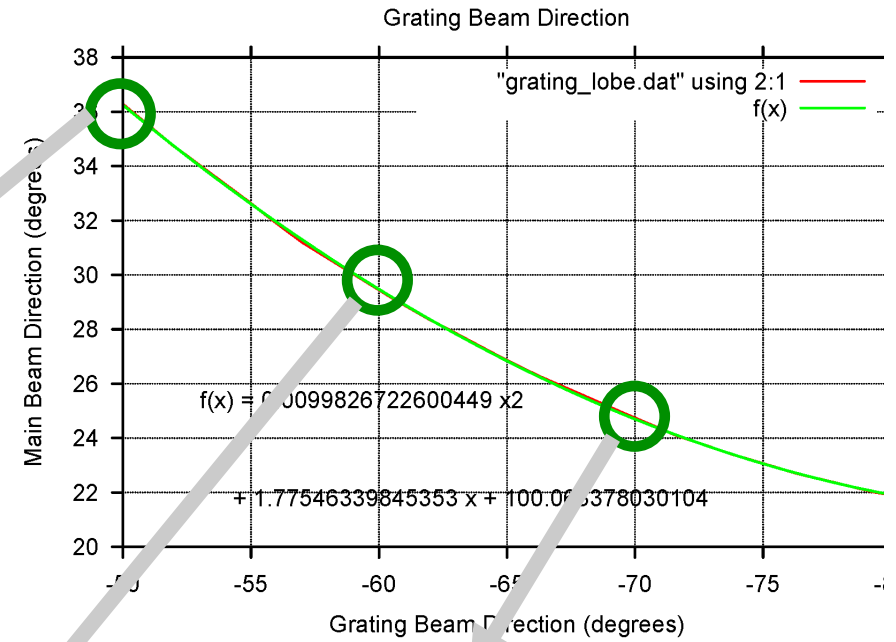
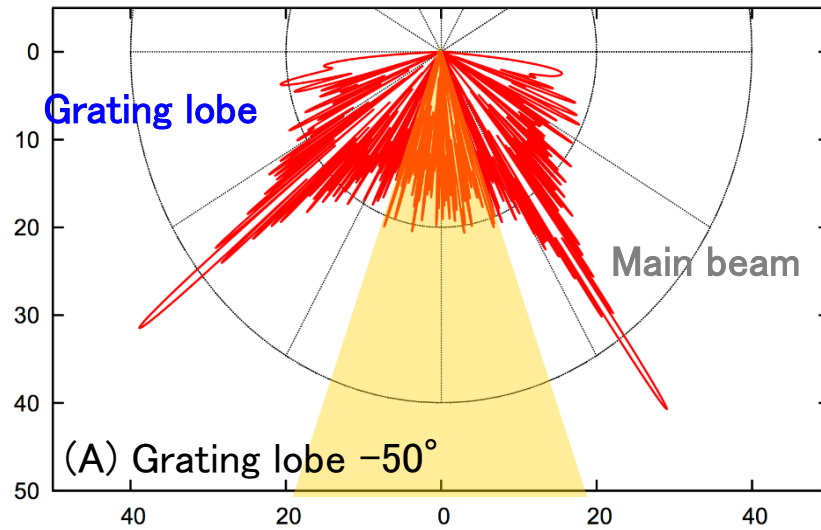


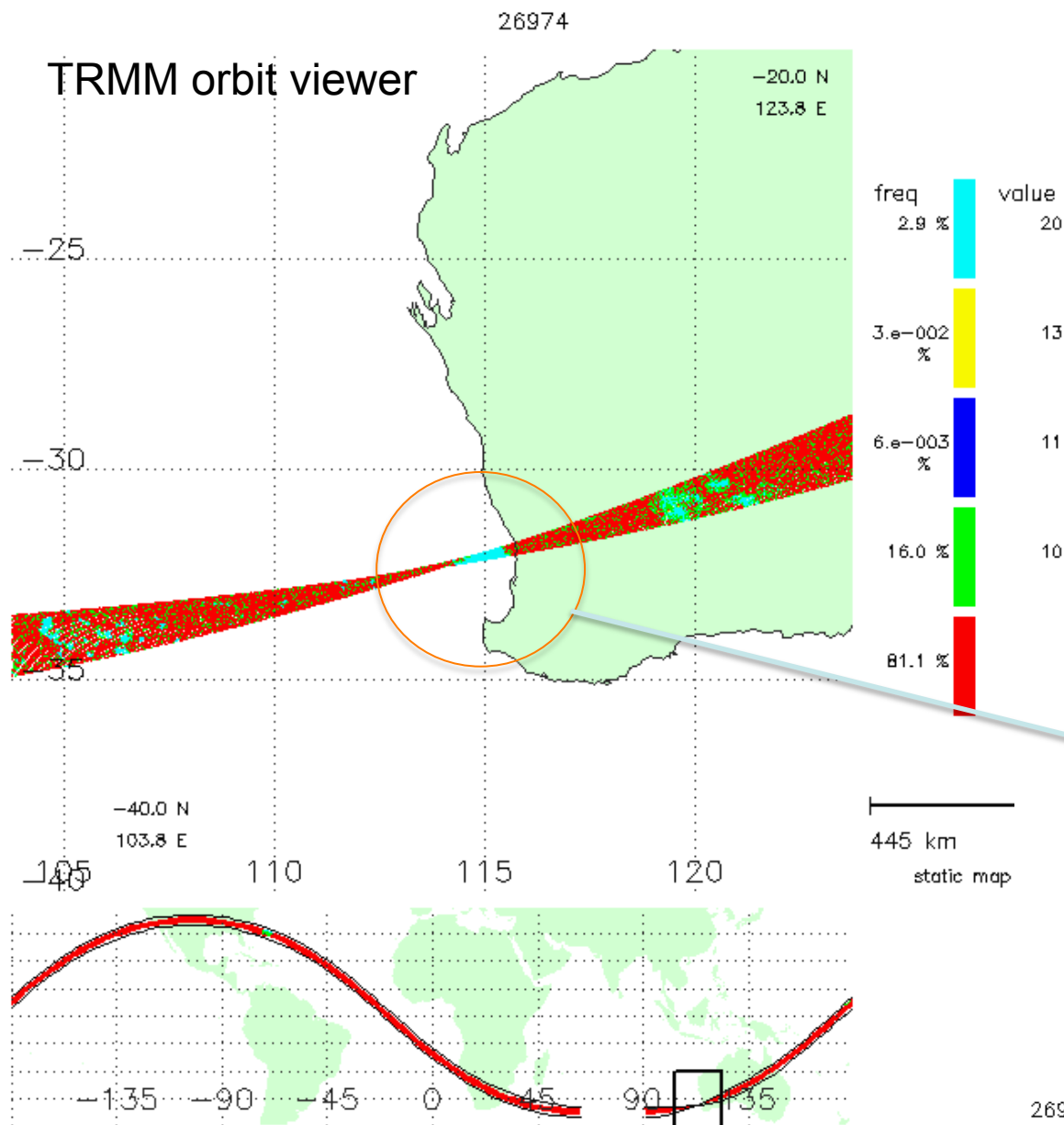


Satellite altitude relative to the Earth surface.  
(fluctuation: 10 km range)



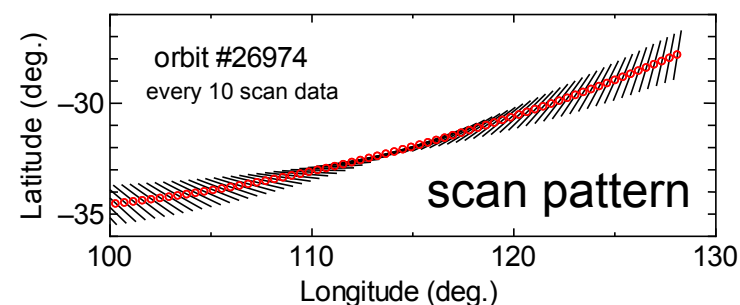
Observation window  
(above the Earth surface)  
Nadir vs. scan edge





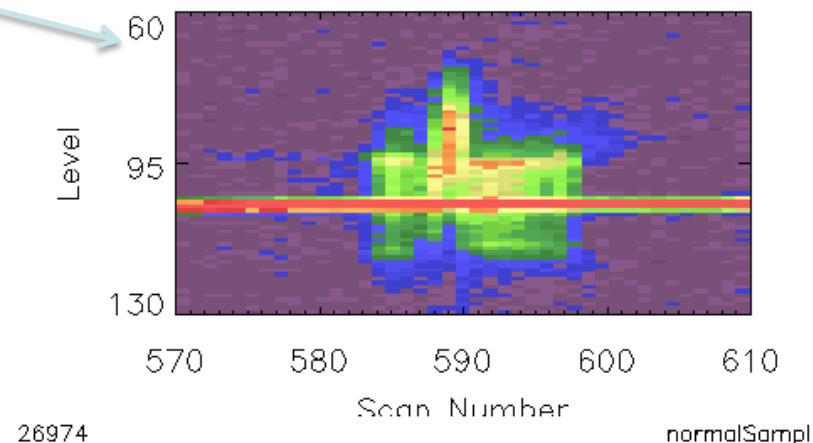
Takahashi and Iguchi, 2007  
(IGARSS)

case: 2002.8.8 orbit #26974



Along Track at tof 25

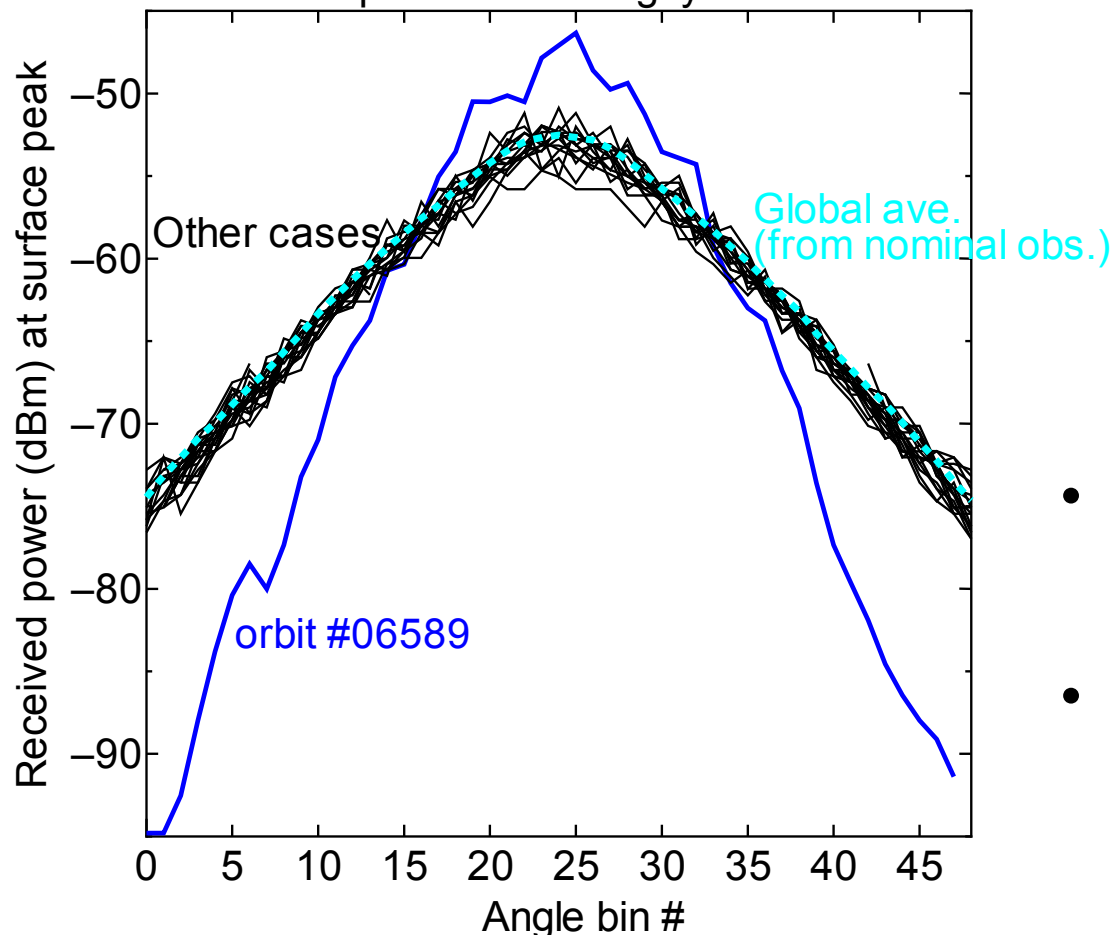
normalSample from 26974



## Sample sea surface echo for various incident angles within very limited area.

10 km diameter area, over ocean (before boost)

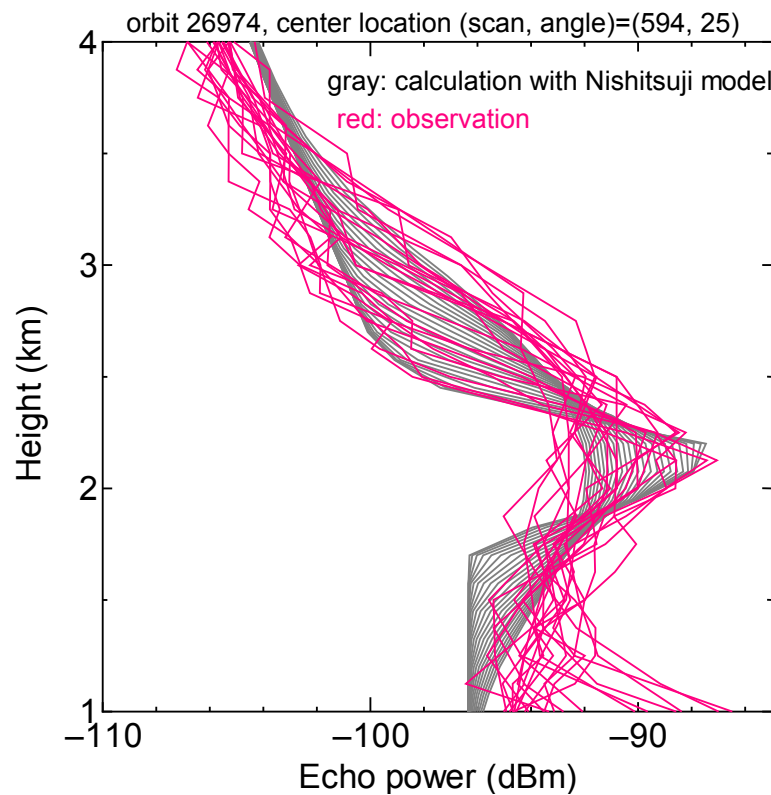
Near focal point of 180 deg. yaw maneuver



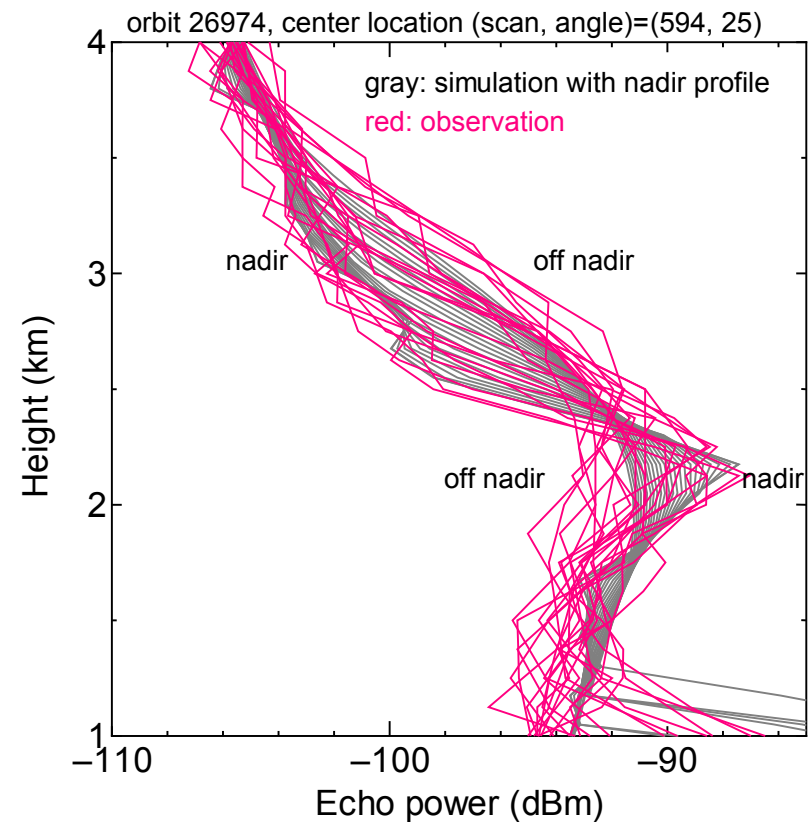
- One case with weak surface echo at the scan edge is found among yaw turn data
  - orbit #06589, 1999.1.19 @ Indian Ocean)
  - Weak power at scan edge & high power near nadir appears at the same time.
- Indication of smooth surface condition (#06589)
- Sea surface wind speed data (e.g. TMI, SSM/I) support this result (weak wind speed at this area).

## Angle bin dependency of BB structure.

observation (red) vs.  
bright band model (grey)

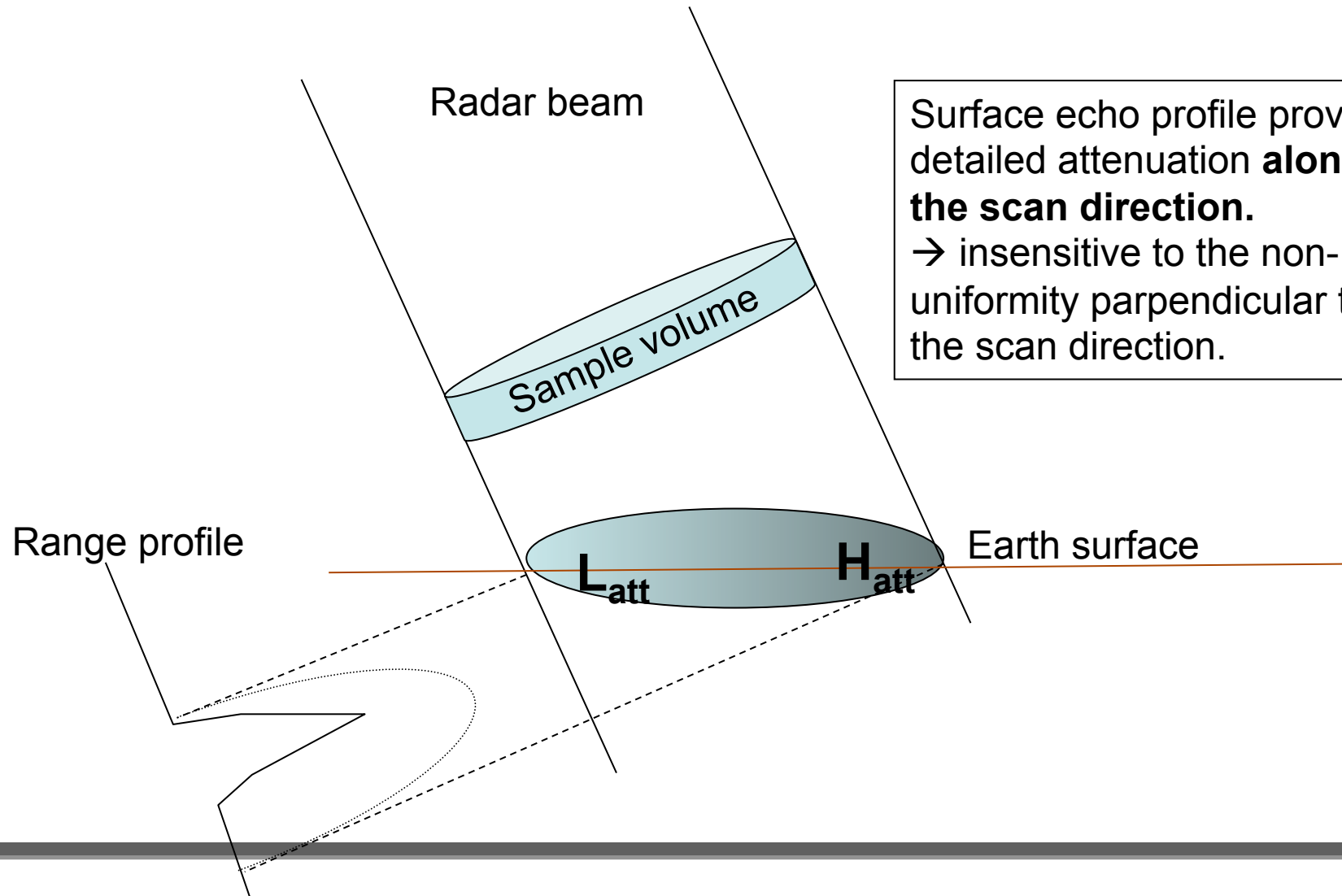


observation (red) vs. simulation  
with nadir profile data (grey)



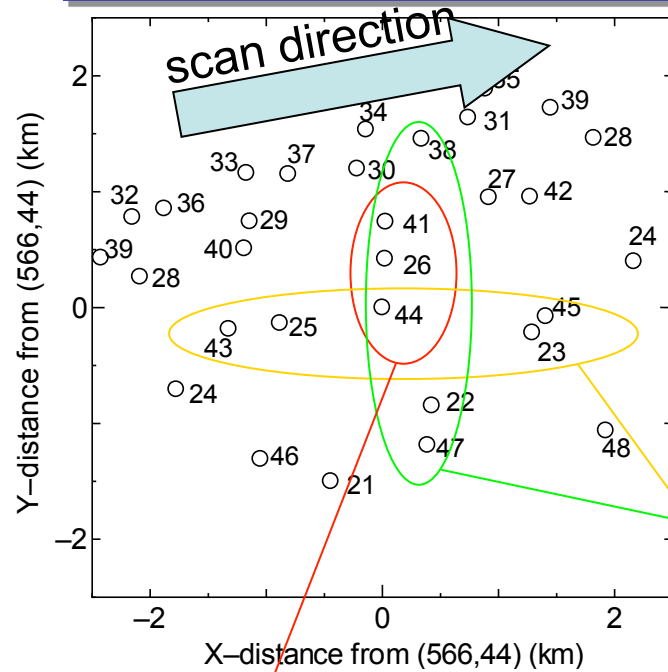
Tendency of angle bin dependency is similar to the model but wider fluctuation.

- Comparison of surface echo profile among different locations and incident angles



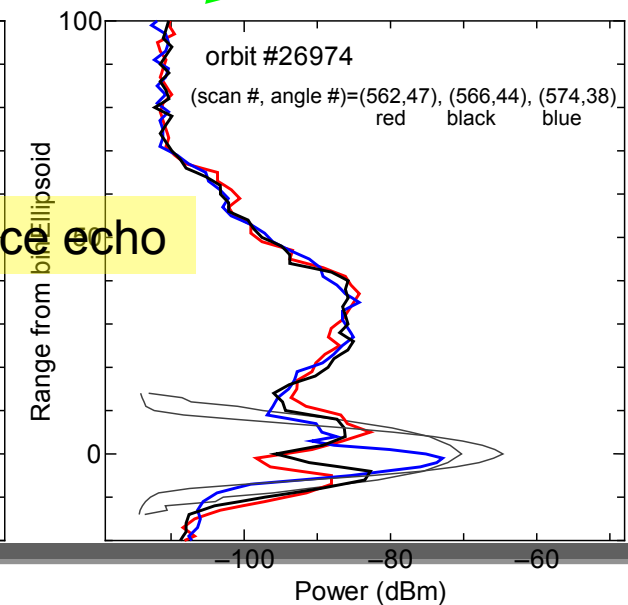
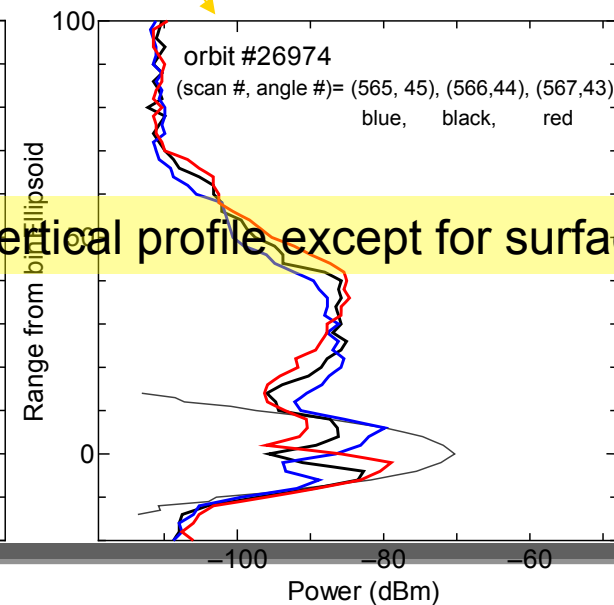
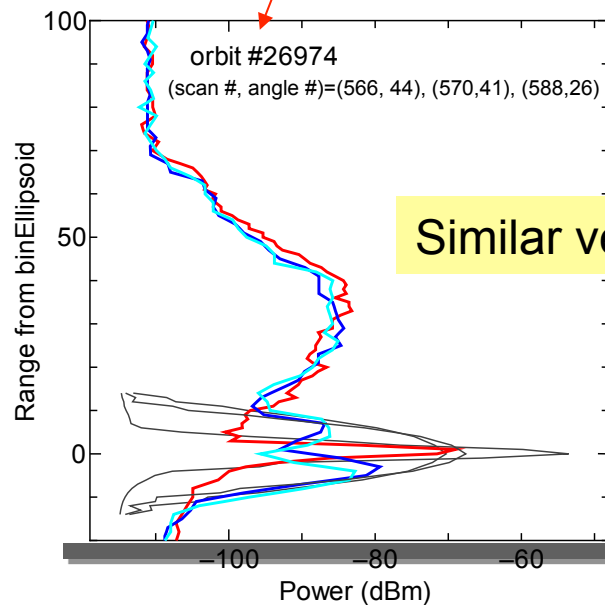
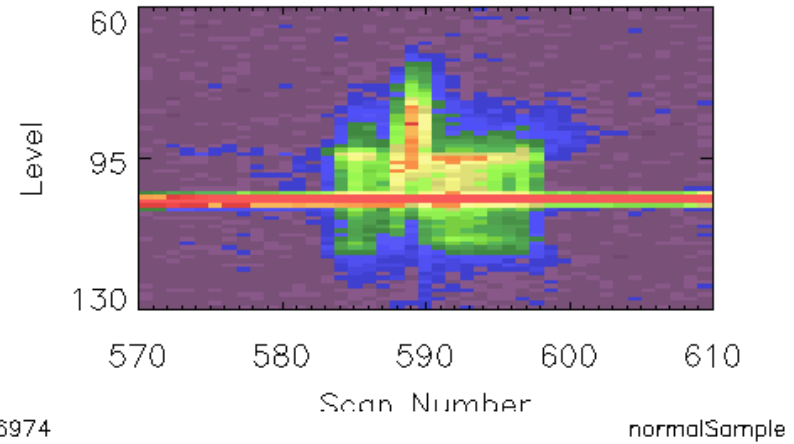
Surface echo profile provides detailed attenuation **along the scan direction**.  
→ insensitive to the non-uniformity perpendicular to the scan direction.

# case orbit #26974

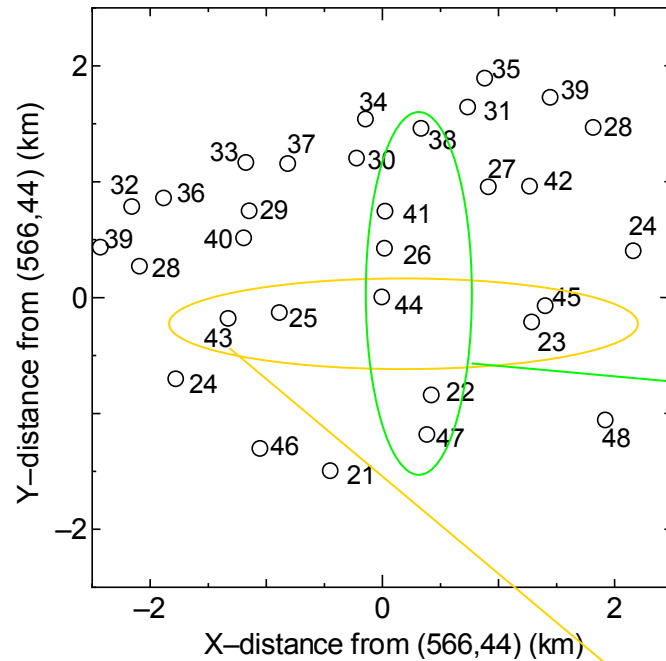


Along Track at fov 25

normalSample from 26974



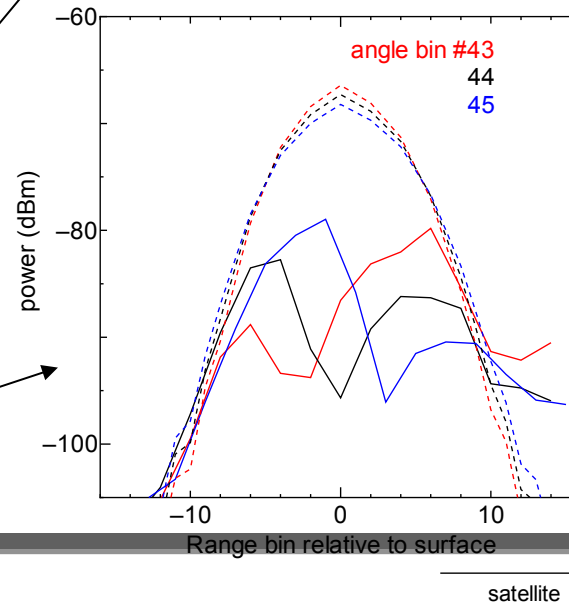
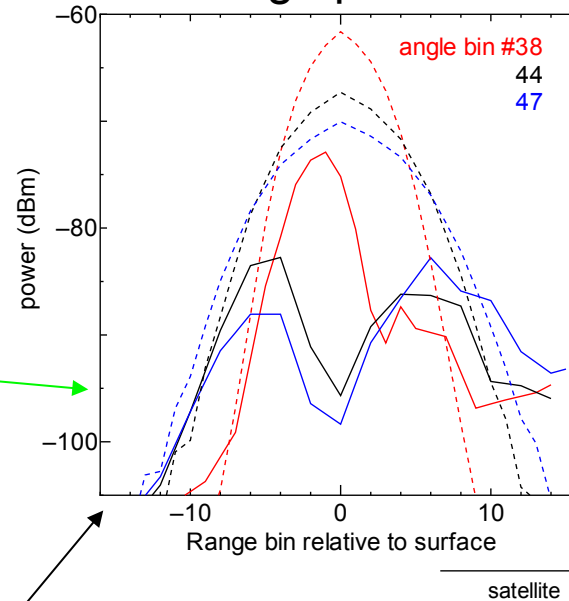
Similar vertical profile except for surface echo



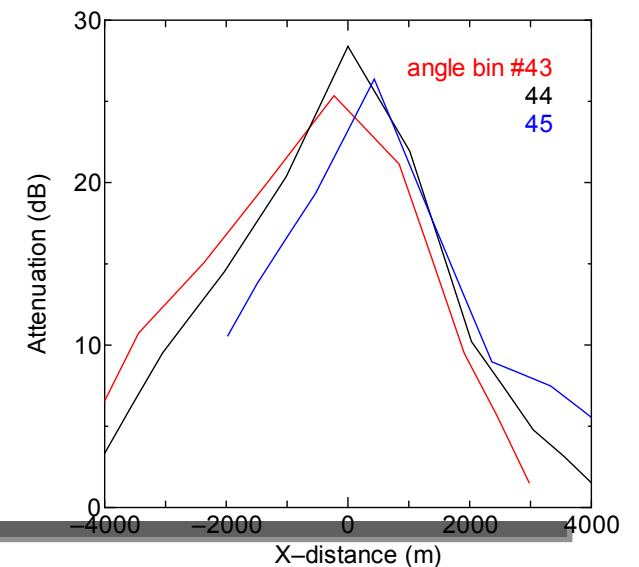
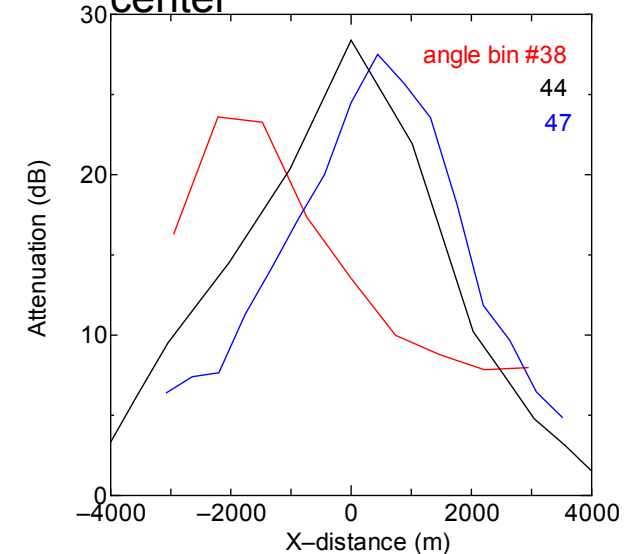
These three foot prints are not on the scan direction. The retrieved attenuation distributions differs, especially angle bin 38, indicating the different echo cell.

These three foot prints are on the scan direction, retrieved attenuation distributions coincides well.

range profile



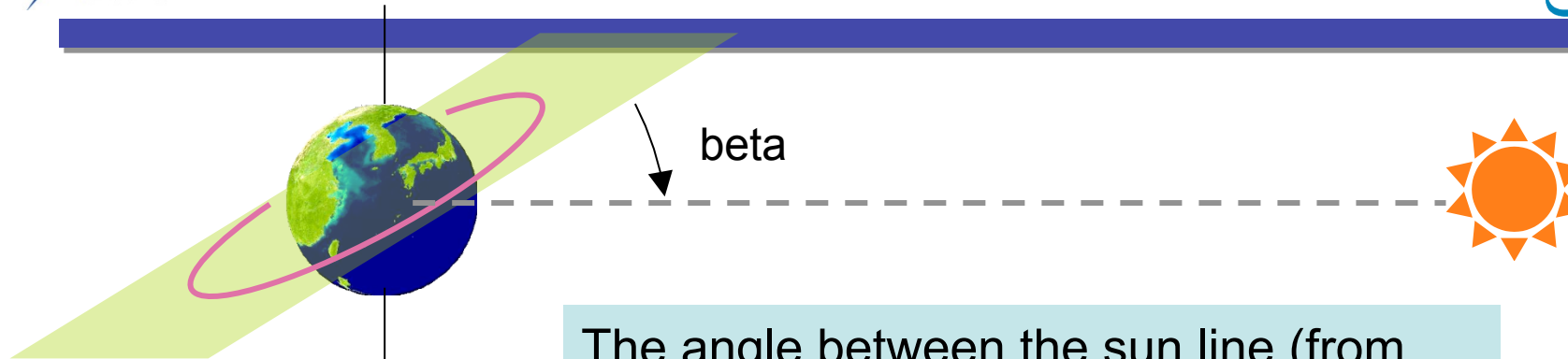
estimated attenuation with correction of beam center



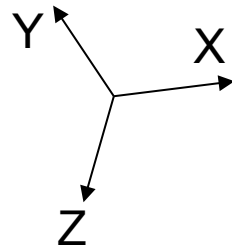




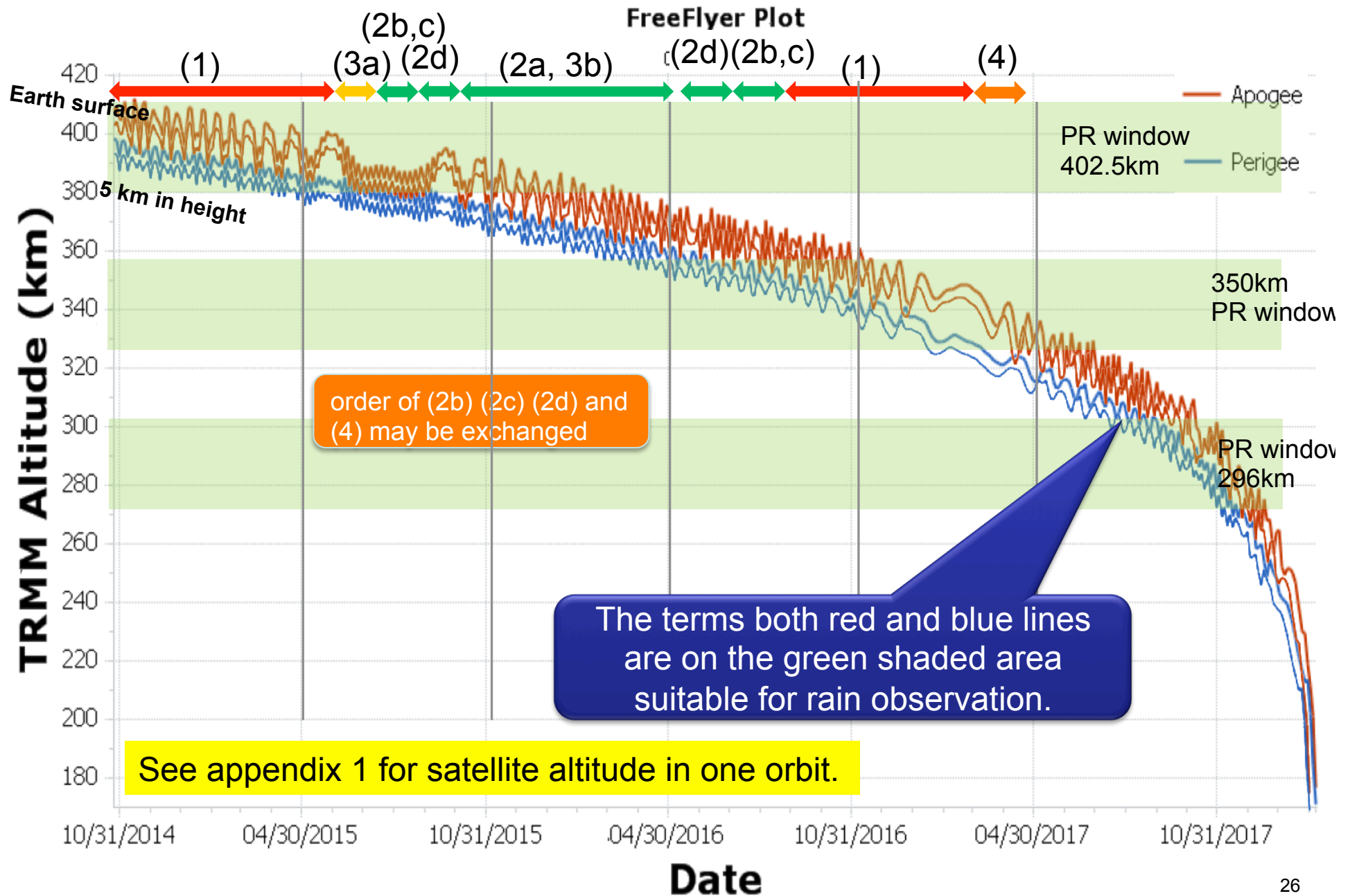
# Solar beta angle



The angle between the sun line (from the Earth's center) and the orbit plane.

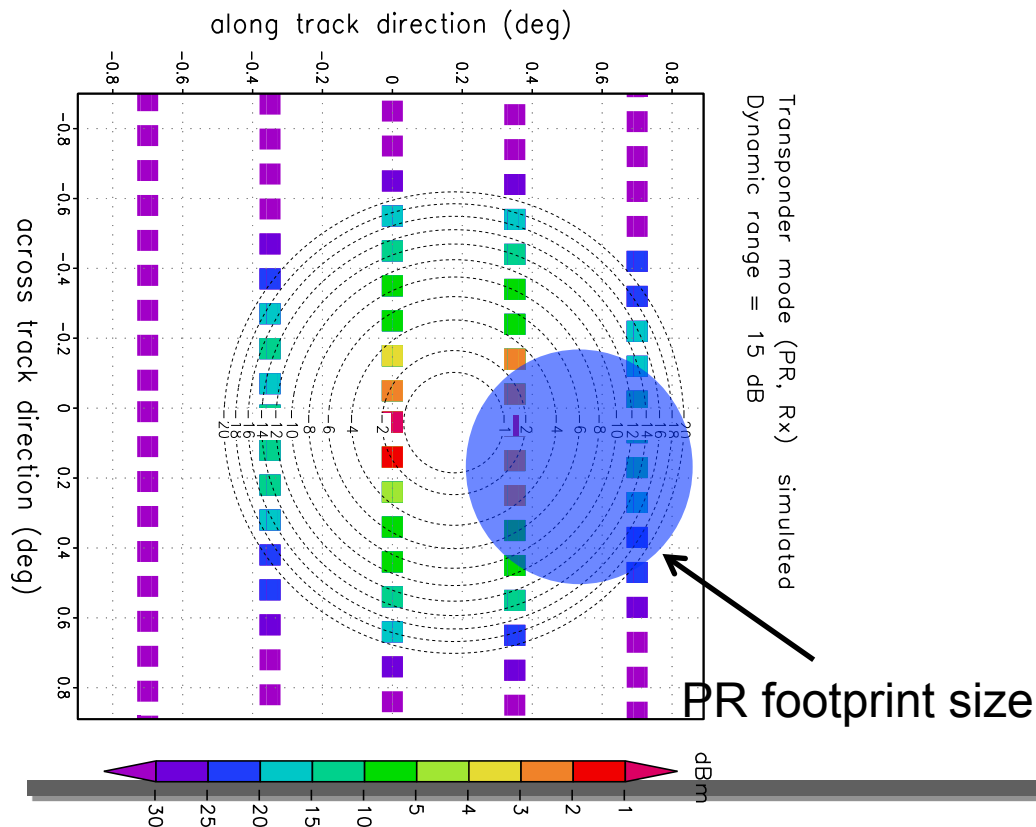


- ✓ When the beta is equal to zero, sun light illuminates  $-Z$  surface of the satellite. (lower temperature in PR)
- ✓ Sun light illuminates x- or y- side of the PR for larger beta .angles (higher temperature in PR)



## TRMM External calibration mode

Squares show the footprint location during external calibration mode, that is **higher sampling density than KaPR interlace observation.**



## GPM KaPR interlace observation

